The Value of Species Distribution Models for Conservation

Tim Newbold, Tom Reader & Francis Gilbert

Outline

- Species distribution mo
- Species richness patte
- Protected areas and sp
- Climate change and SD

Species Distribution Models

Data on where the species is known to occur → + Data on the environment at these locations → A model to relate them – what does the species require? → Produce a map of predicted distribution

Applications

- Identifying biodiversity hotspots
- Evaluating protected areas
- Finding new populations of rare species
- Identifying sites for reintroductions
- Predicting impacts of climate change

Species Richness Patterns

- Many studies have investigated correlates of species richness
- E.g. Butterflies in Finland - Kivinen et al. (2007)

Distribution Models and Richness

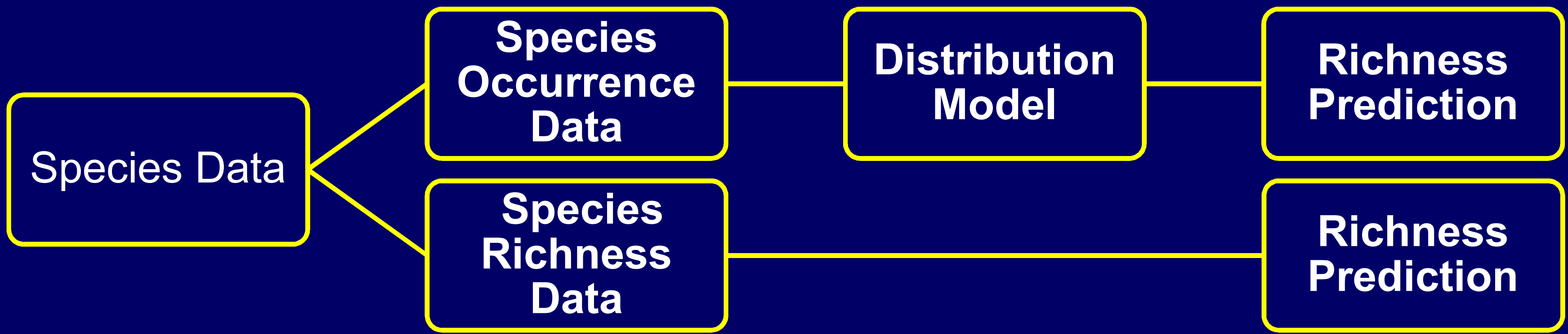
- Few attempts to use SDMs to predict richness
- Mexican reptiles and amphibians - Garcia (2006)
- Comparison of methods

Egyptian Mammals and Butterflies

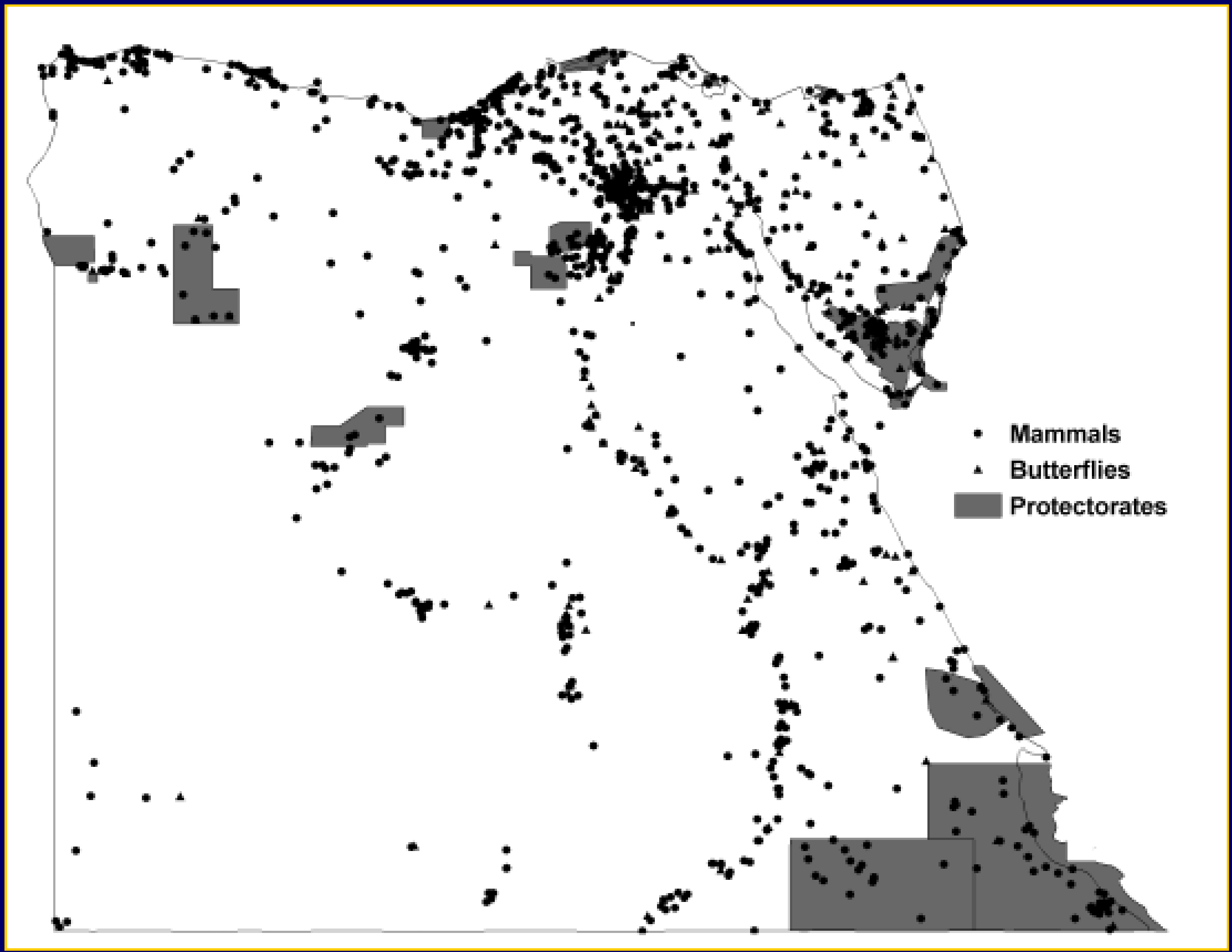
- Butterflies – 2 endemics, 2 near-endemics
- Mammals – 4 endemics, 10 near-endemics

Methods of Predicting Richness

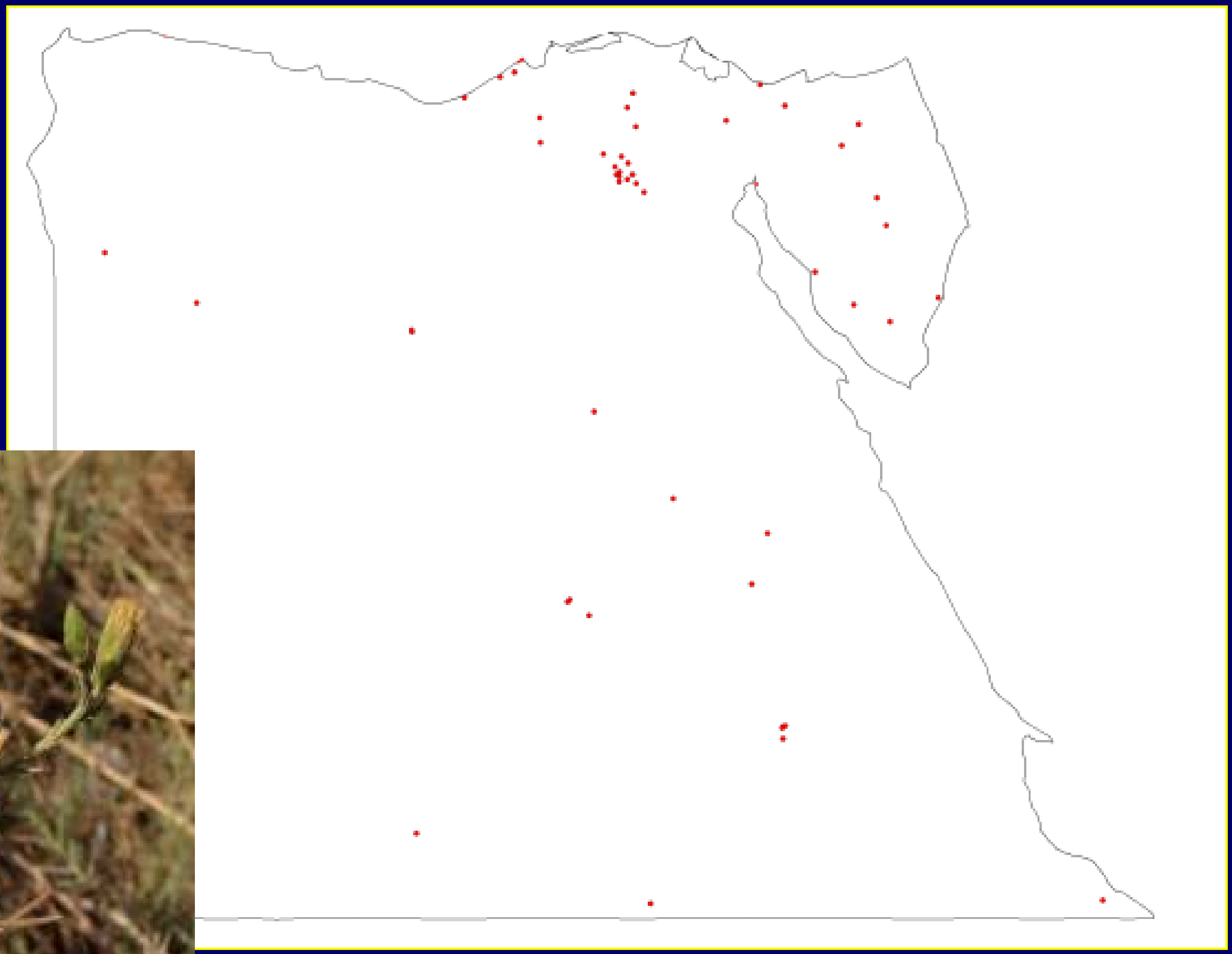
- Compared 2 methods
- Generating distribution models and summing them
- Modelling richness patterns directly



Data & Protected Areas



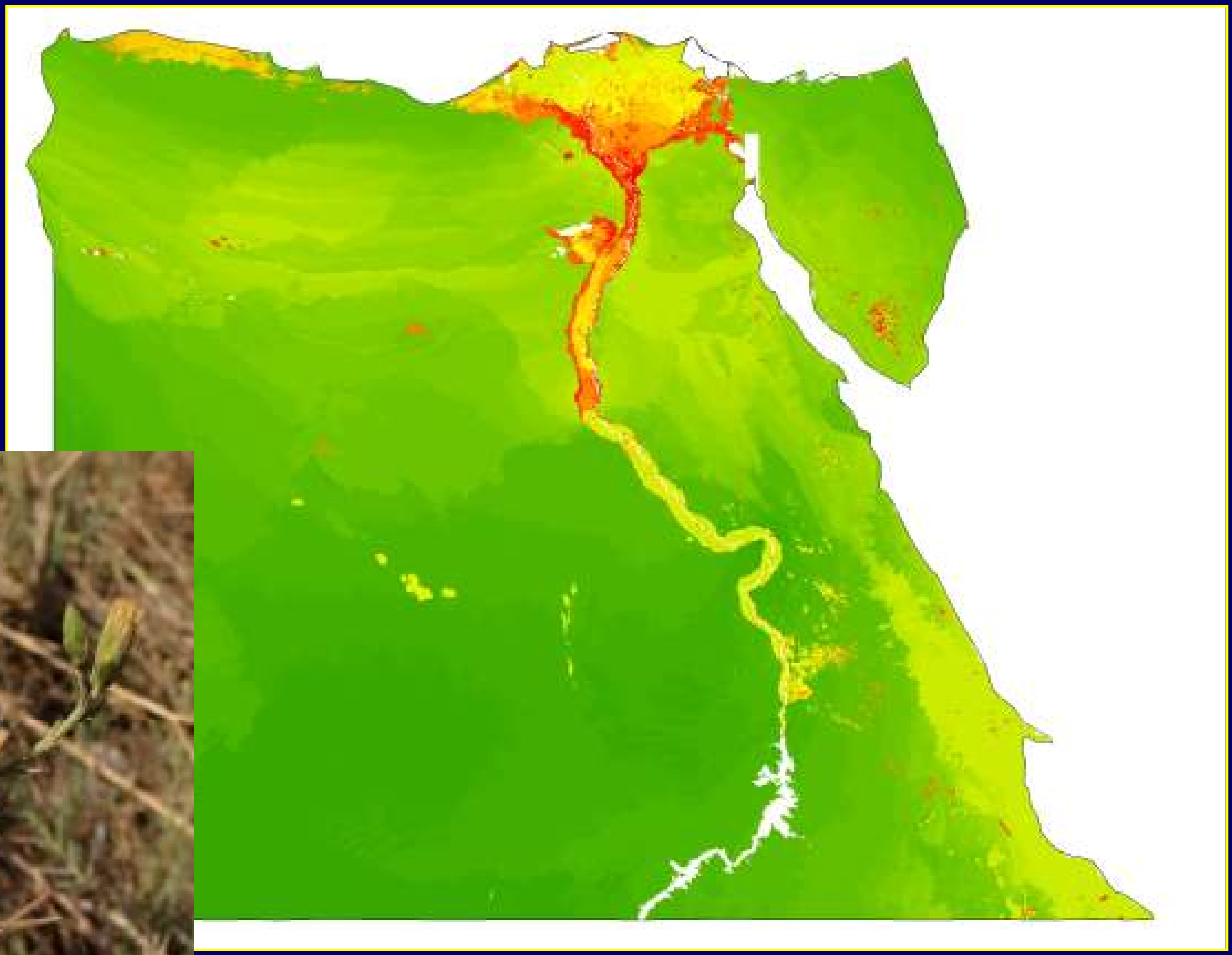
Species Records



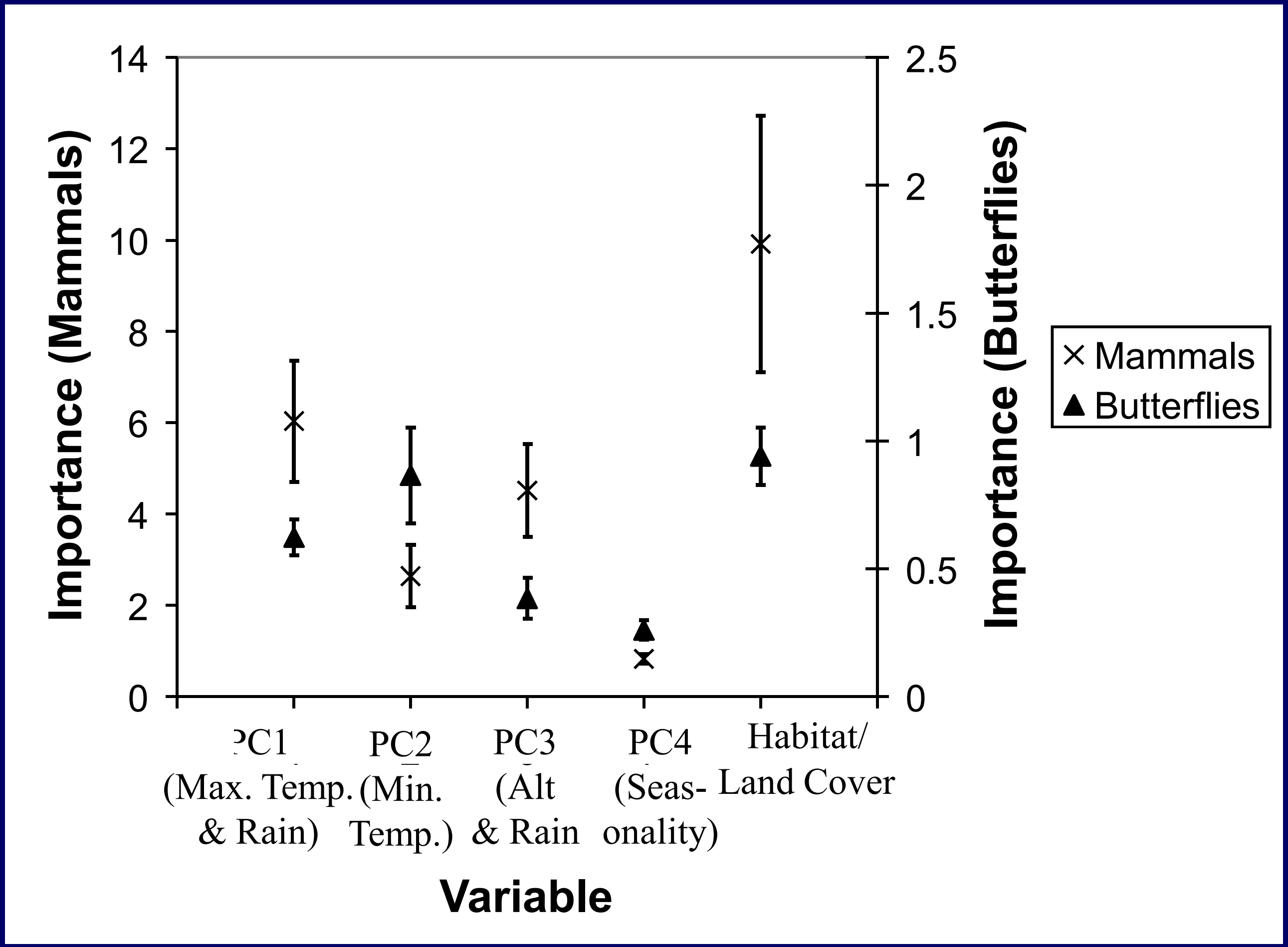
Environmental Variables

- Climate
- Principal Components Analysis → 4 PCs
- Habitat

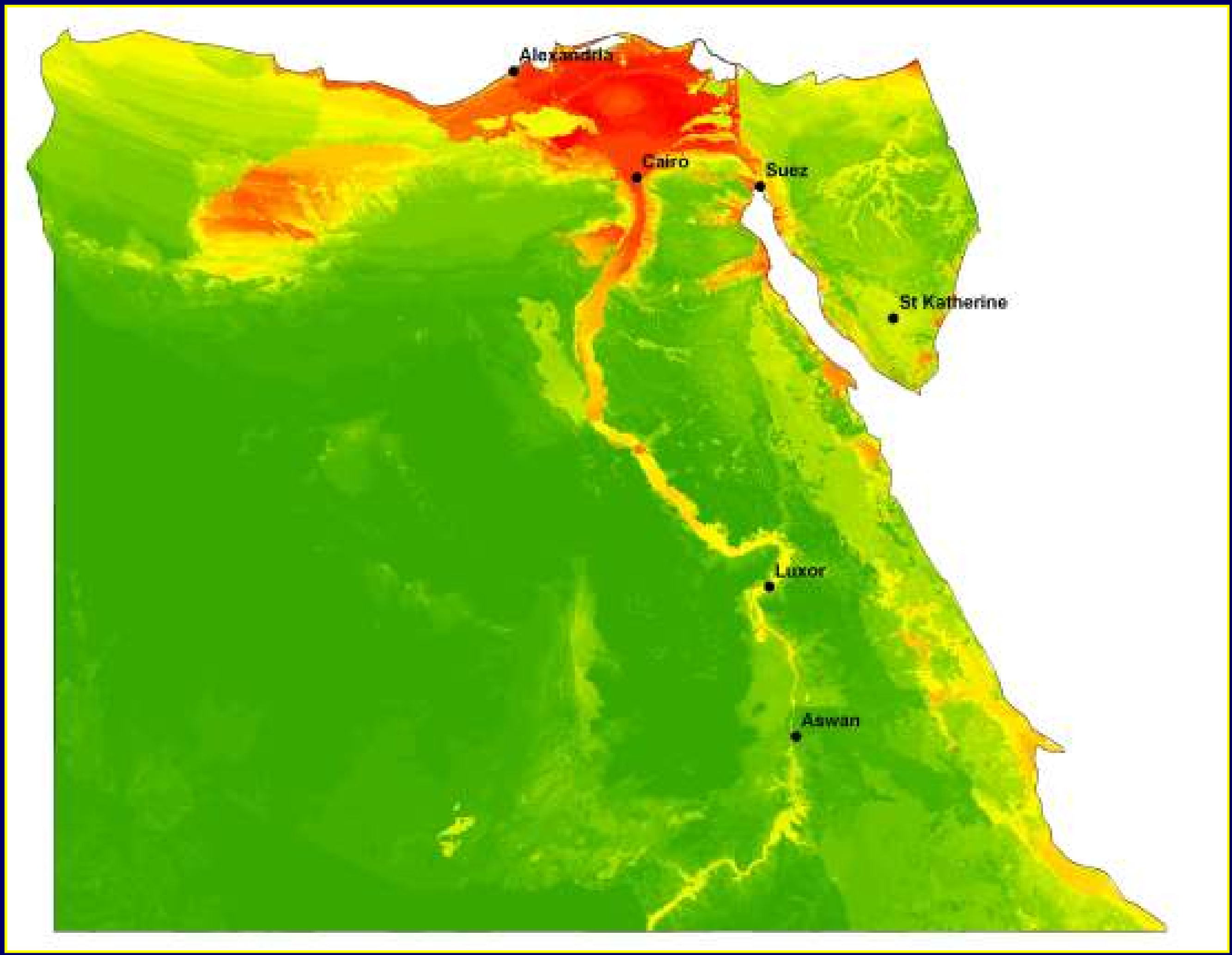
Distribution Model



Variable Importance



Distribution Model Sum



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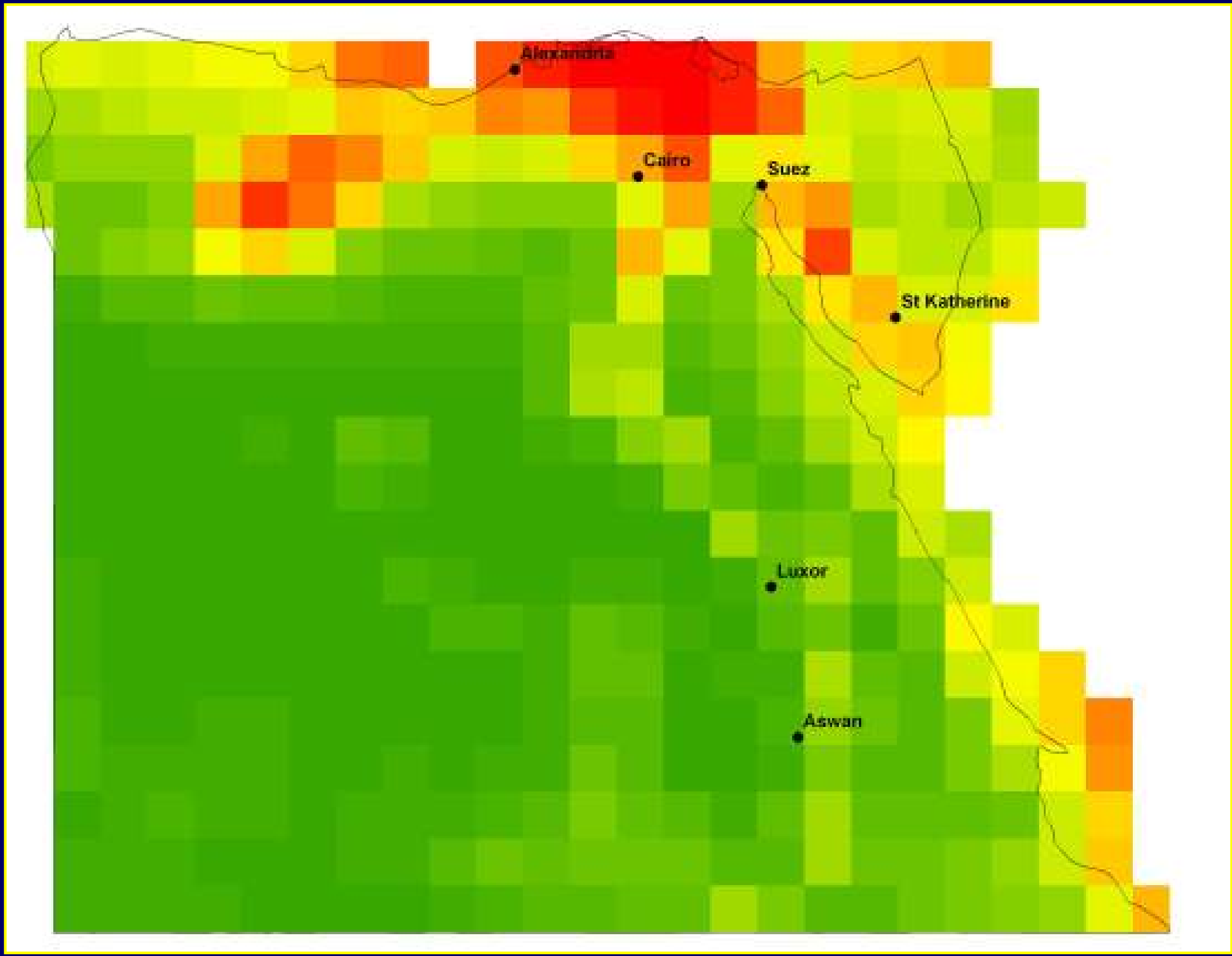

Modelling Richness Directly

- Species richness calculated for sampled 0.5° cells
- Modelled using GLM with Poisson errors
- Same variables as before

GLM Results

Term		Deviance Explained	
		Butterflies	Mammals
PC 1	Max. Temp. & Rain	2.18	5.52
$(PC\ 1)^2$		1.24	1.4
PCA 2	Min. Temp.	NS	NS
$(PC\ 2)^2$		NS	0.36
PC 3	Altitude & Rain	NS	4.99
$(PC\ 3)^2$		1.67	NS
PC 4	Seasonality	0.59	NS
$(PC\ 4)^2$		2.36	0.35
Habitat		1.35	5.37
Total		10.04	20.29

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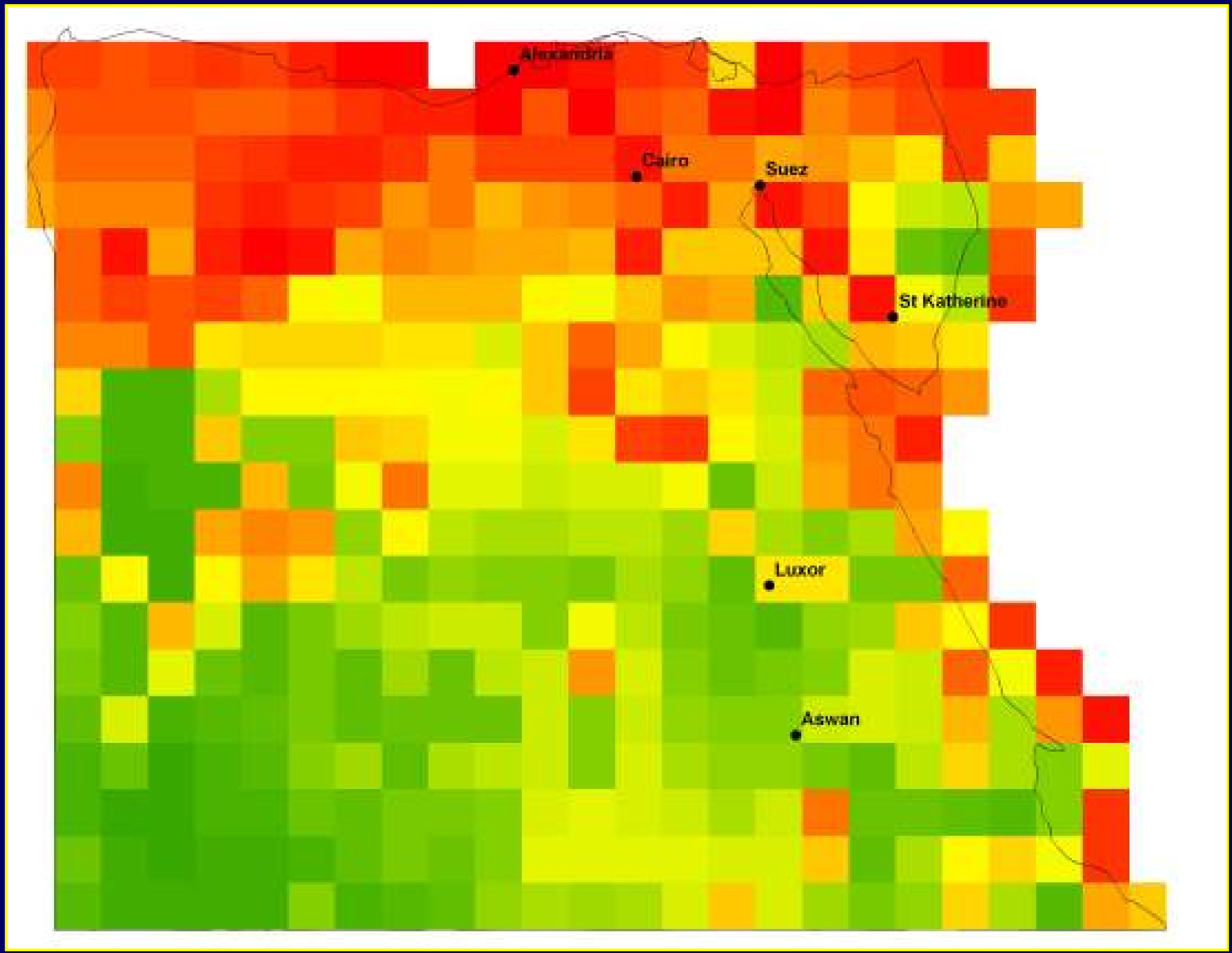
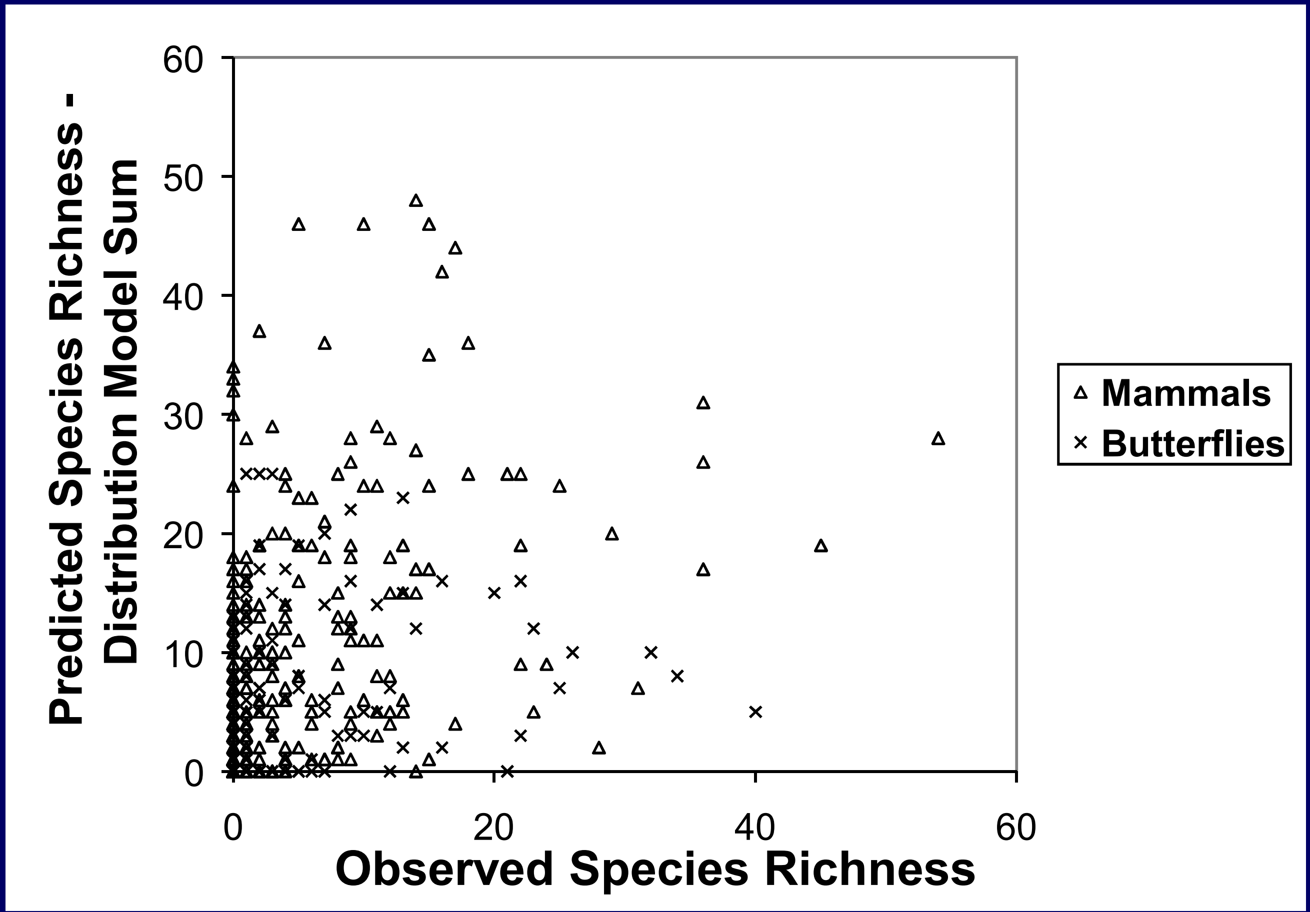
Species Richness Model

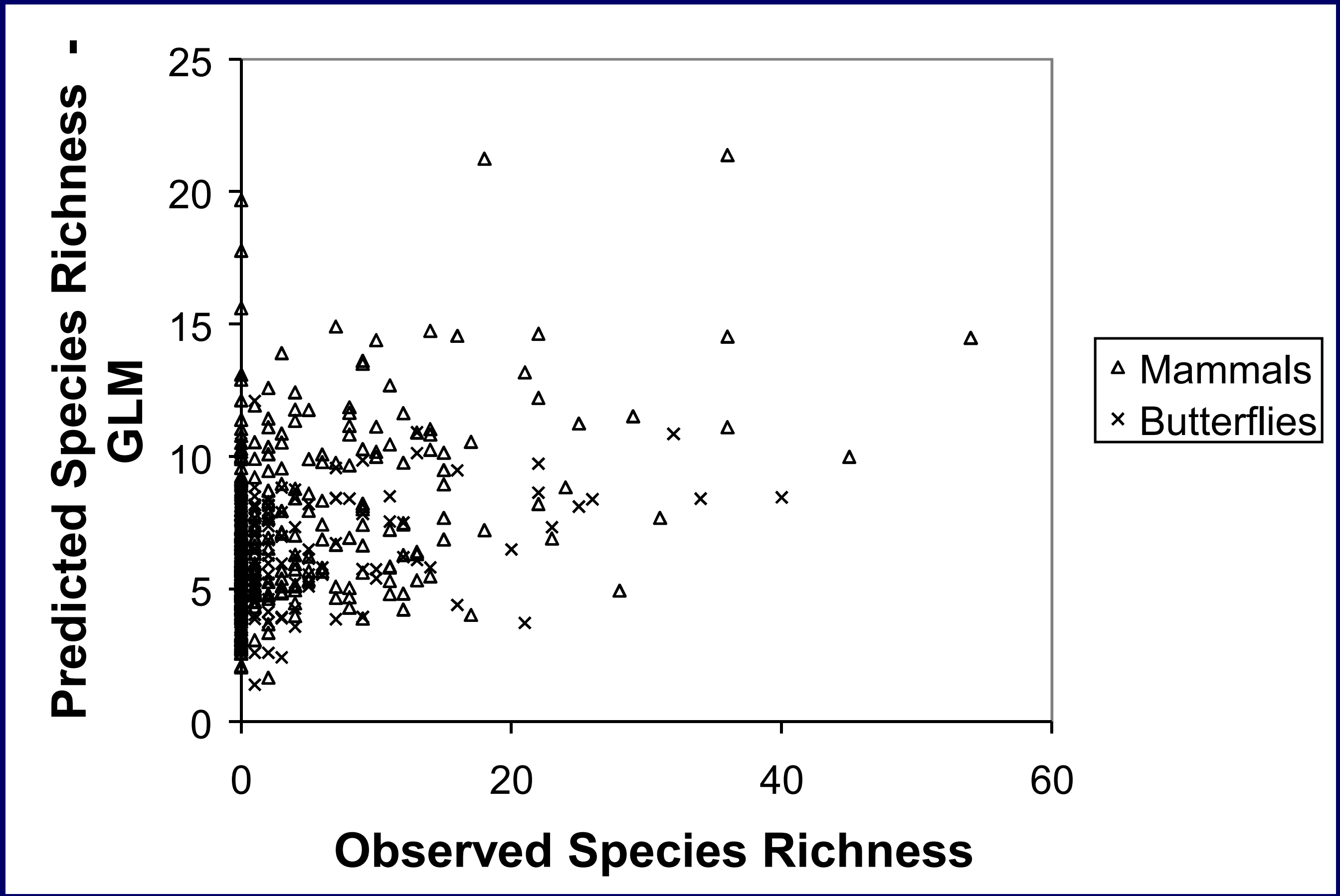


Agreement with Observed Richness



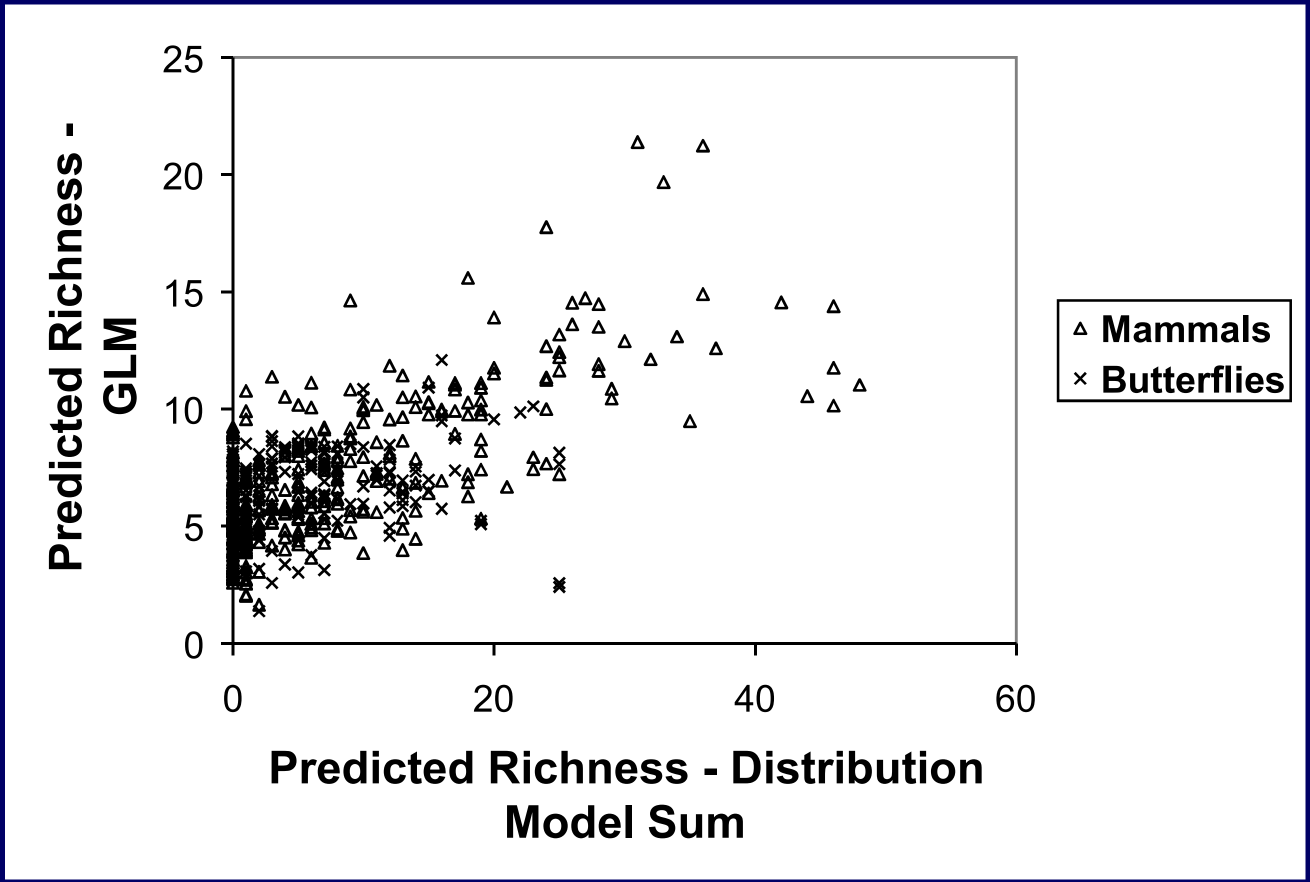
Butterflies - $r_s = 0.456$, N = 357, $p < 0.001$
Mammals - $r_s = 0.586$, N = 362, $p < 0.001$

Agreement with Observed Richness



Butterflies - $r_s = 0.226$, N = 357, $p < 0.001$
Mammals - $r_s = 0.534$, N = 362, $p < 0.001$

Agreement Between Methods

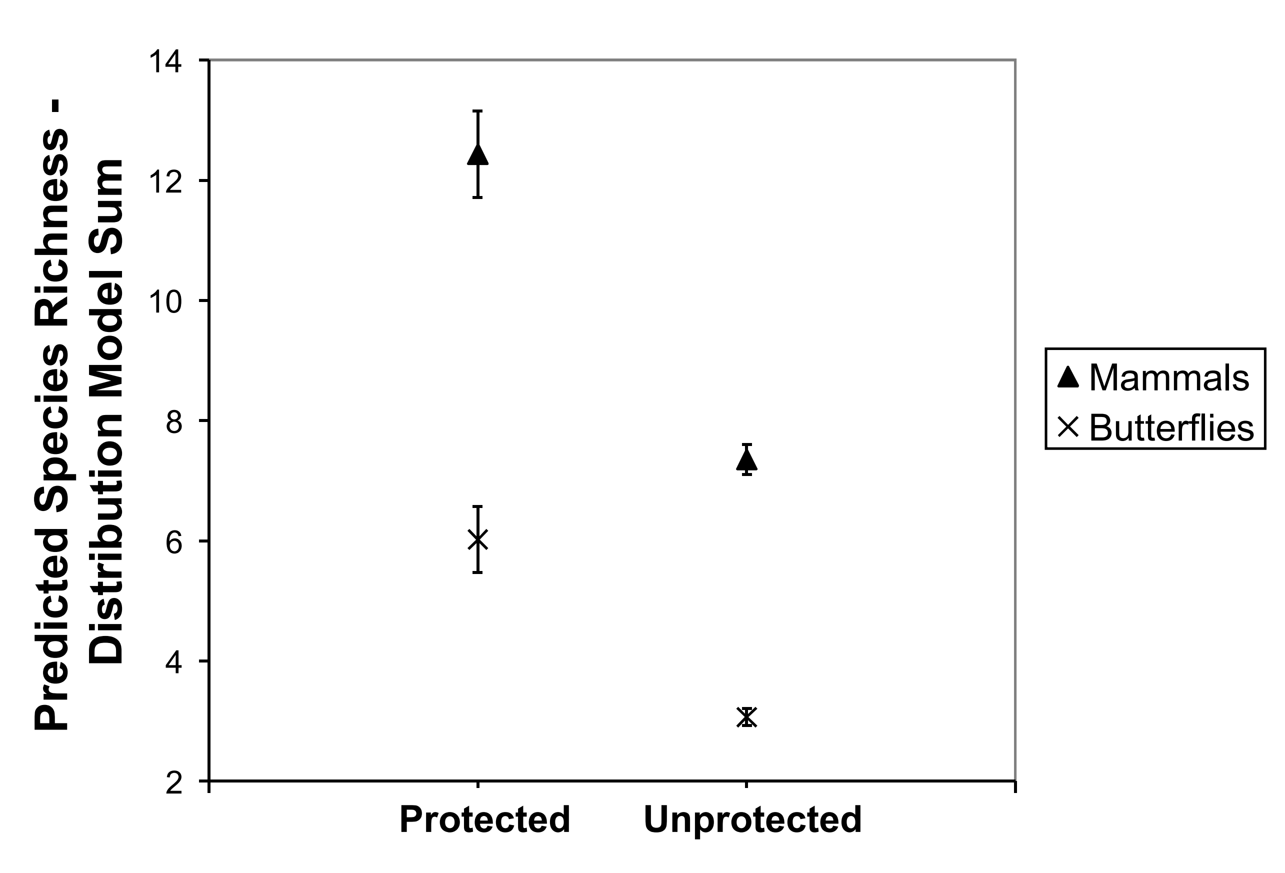


Butterflies - $r_s = 0.501$, $N = 357$, $p < 0.001$
Mammals - $r_s = 0.653$, $N = 357$, $p < 0.001$

Egypt's Protected Areas

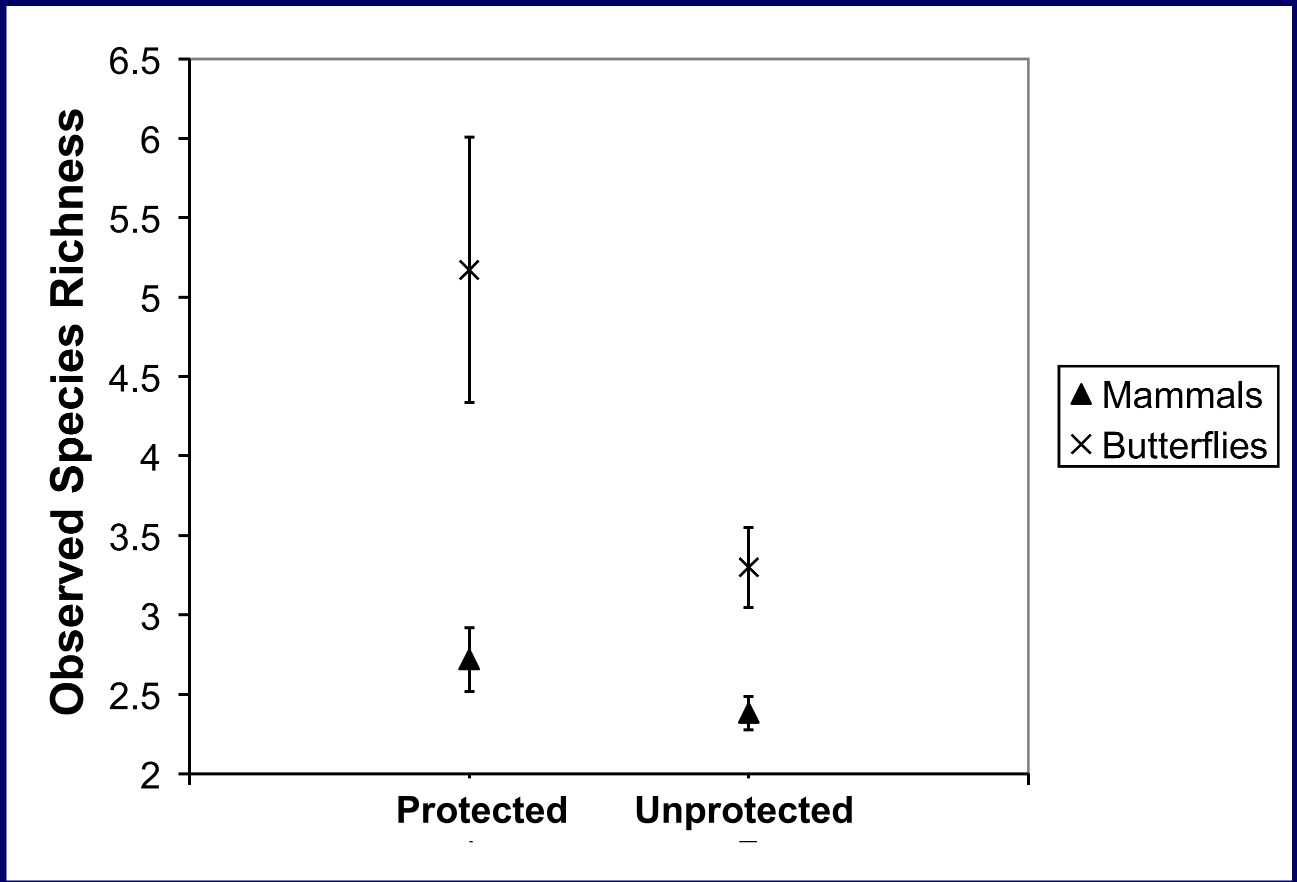
- 27 protected areas
- Gazetted since 1983
- Some knowledge of diversity patterns
- Cover 11% of land surface
- Do they represent diversity well?

Protected Areas



Butterflies - Mann-Whitney test: $U = 67976$, $N = 1983$, $p < 0.001$
Mammals - Mann-Whitney test: $U = 71849$, $N = 1983$, $p < 0.001$

Protected Areas



Butterflies - Mann-Whitney test: U = 5500, N = 298, p = 0.009
Mammals - Mann-Whitney test: U = 67381, N = 1143, p = 0.006

Conclusions

- Neither method matched observed species richness perfectly
- Many factors not captured e.g. species interactions, soils, microclimate, dispersal history
- 2 methods produced similar results
- Model of richness useful when species identity unknown e.g. richness estimators
- Protected areas represent richness well

Climate Change is Already Affecting Species

- Distributions shifting northwards and upwards
- Spring events earlier
- Population dynamics changes
- Community composition changes

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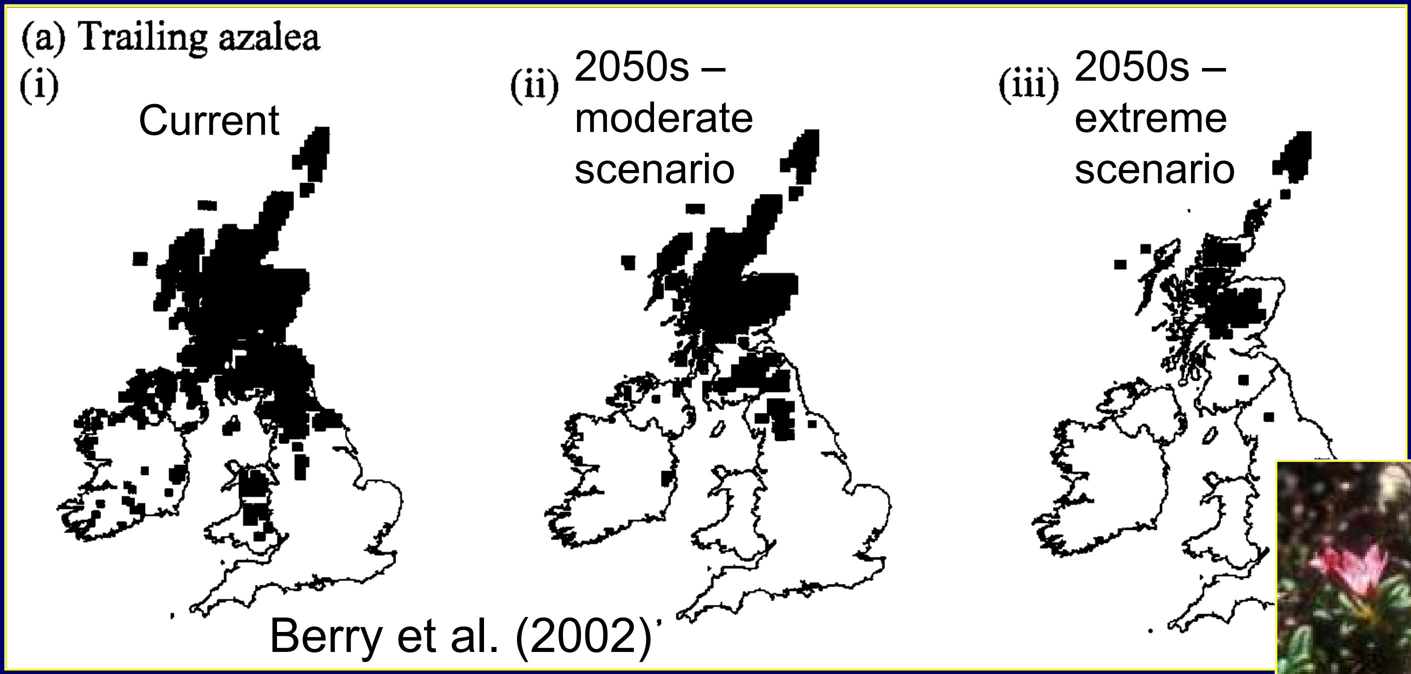
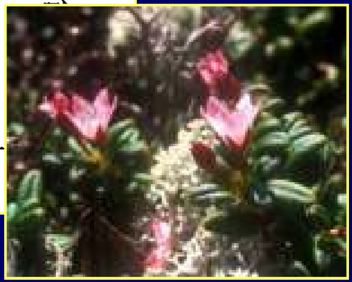
Species Distribution Models

- Can predict future distributions
- Model coefficients applied to predicted future climates
- Previous studies predicted large shifts and alarming extinction rates





Species Distribution Models

- Thomas et al. (2004)
- Used distribution models
- Several taxonomic groups
- Different regions worldwide
- 15-37% of species "committed to extinction"

Species Distribution Models

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The Guardian

An unnatural disaster

- Global warming to kill off 1m species
- Scientists shocked by results of research
- Third of life forms doomed by 2050

Paul Brown
Environment correspondent

Climate change over the next 50 years is expected to drive a quarter of land animals and plants into extinction, according to the first comprehensive study into the effect of higher temperatures on the natural world.

The sheer scale of the disaster facing the planet shocked those involved in the research. They estimate that more than 1 million species will be lost by 2050.

The results are described as "terrifying" by Chris Thomas, professor of conservation biology at Leeds University, who is lead author of the research from four continents published today in the magazine Nature.

Much of that loss – more than one in 10 of all plants and animals – is already irre-

tralia, Central and South America, and South Africa, showed that species living in mountainous areas had a greater chance of survival because they could simply move uphill to get cooler.

Those in flatter areas such as Brazil, Mexico and Australia, were more vulnerable, faced with the impossible task of moving thousands of miles to find suitable conditions.

Birds, which had the greatest chance of escape, could in theory move to a more suitable climate but the trees and other habitat they needed for survival could not keep pace and all would die.

Professor Thomas said: "When scientists set about research they hope to come up with definite results, but what we found we wish we had not. It was far, far worse than we thought, and what we have discovered may even be an

Continued

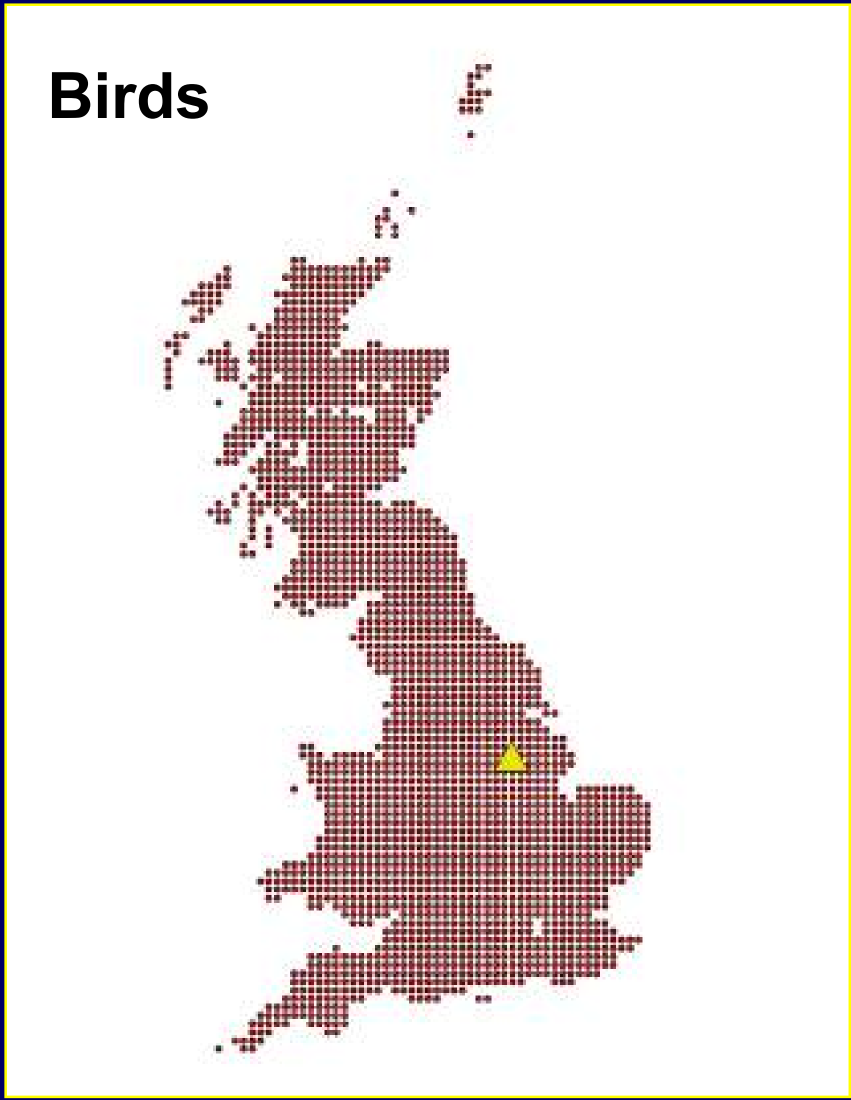
Species Distribution Models

- Difficult to assess accuracy because changes haven't happened
- Solution: Predict changes that have happened


Data

- 30-year time series (1972-2002):
  - British hoverflies (n = 256) and birds (n = 32)
  - Nationwide occurrence
  - Single-point abundance
  - Climate data (UKCIP)
  - Habitat data (ITE land cover)
  - Agricultural data (Edina censuses)
  - Divided into five or six-year periods

Data



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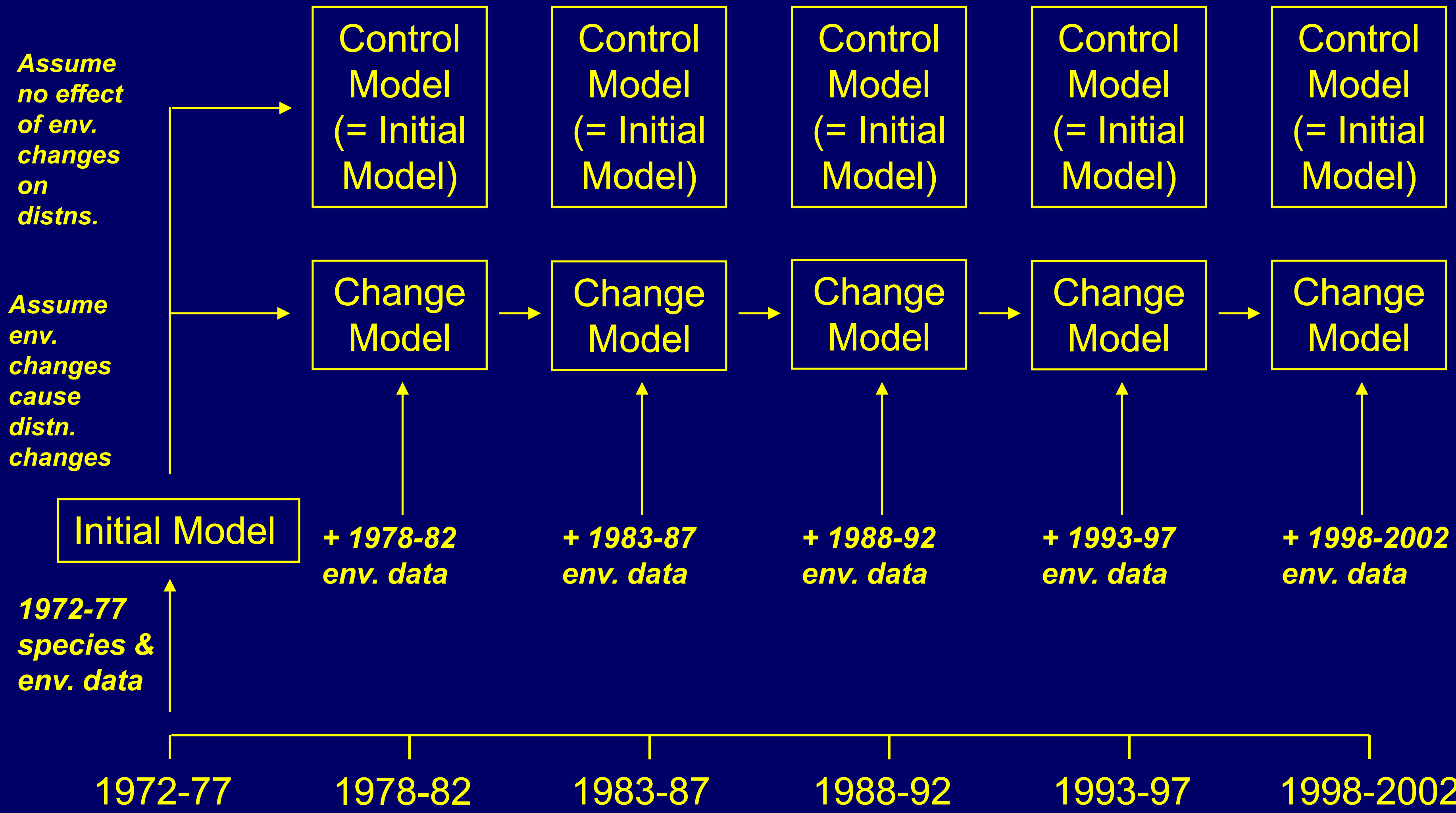
The Models


Assume no effect of env. changes on distns.
Assume env. changes cause distn. changes
Control Model (= Initial Model)
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+ 1978-82 env. data
+ 1983-87 env. data
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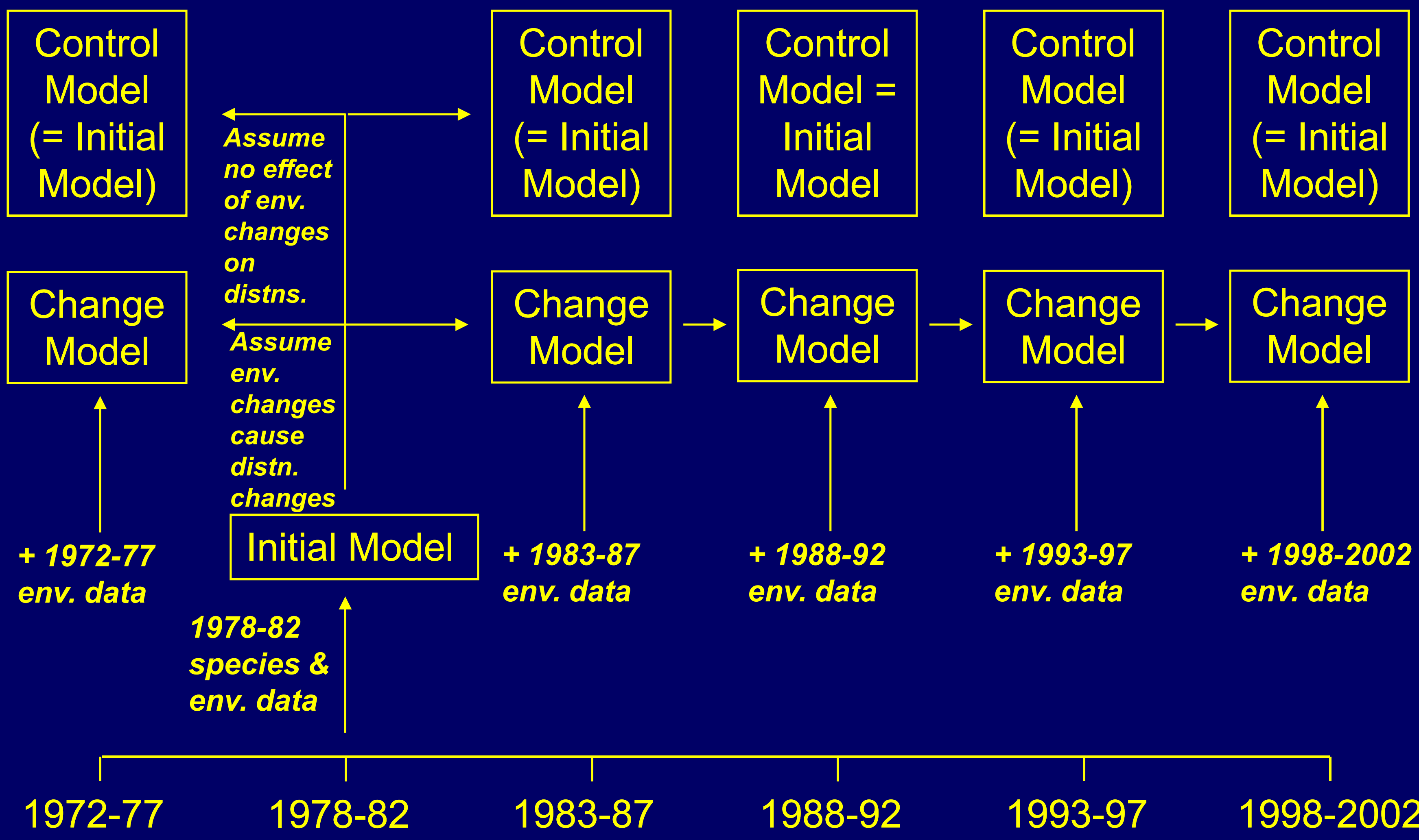
The Models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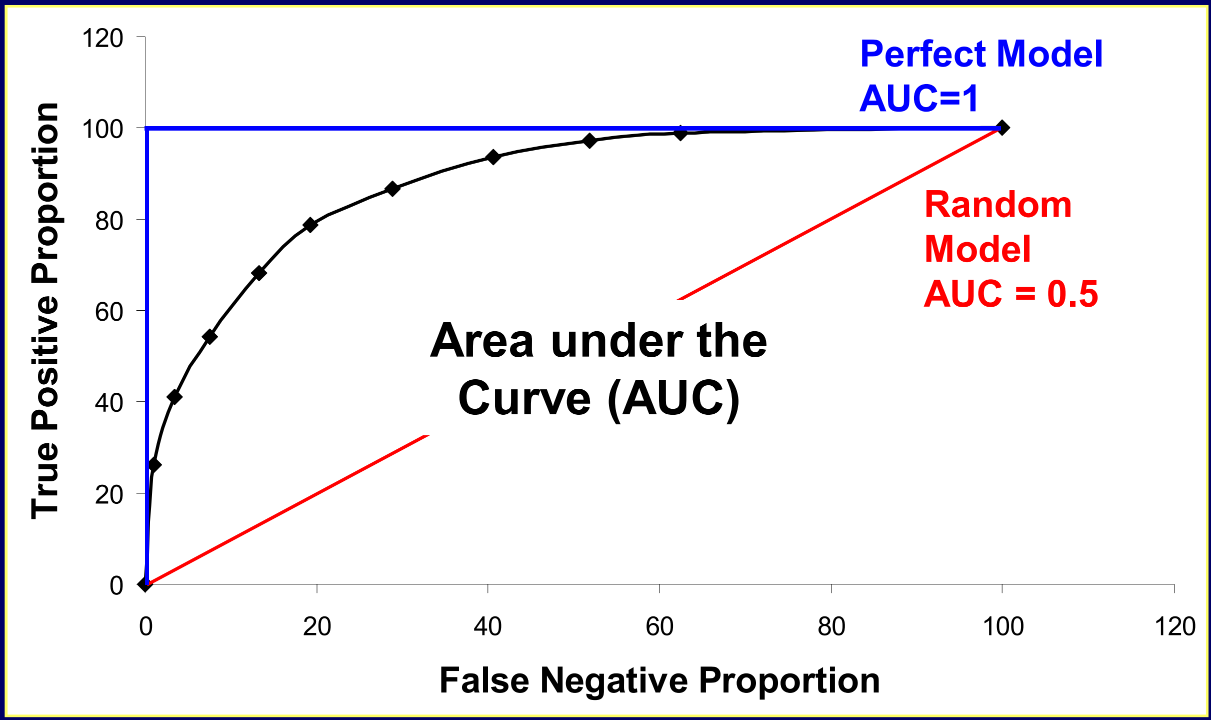
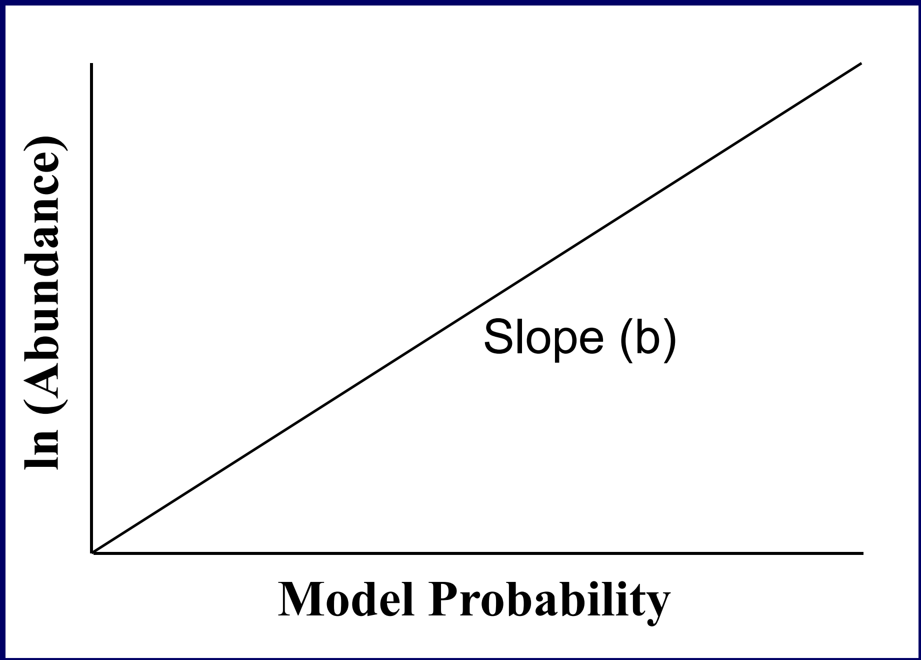
Testing the Models

- Against nationwide occurrence:
  - AUC statistic

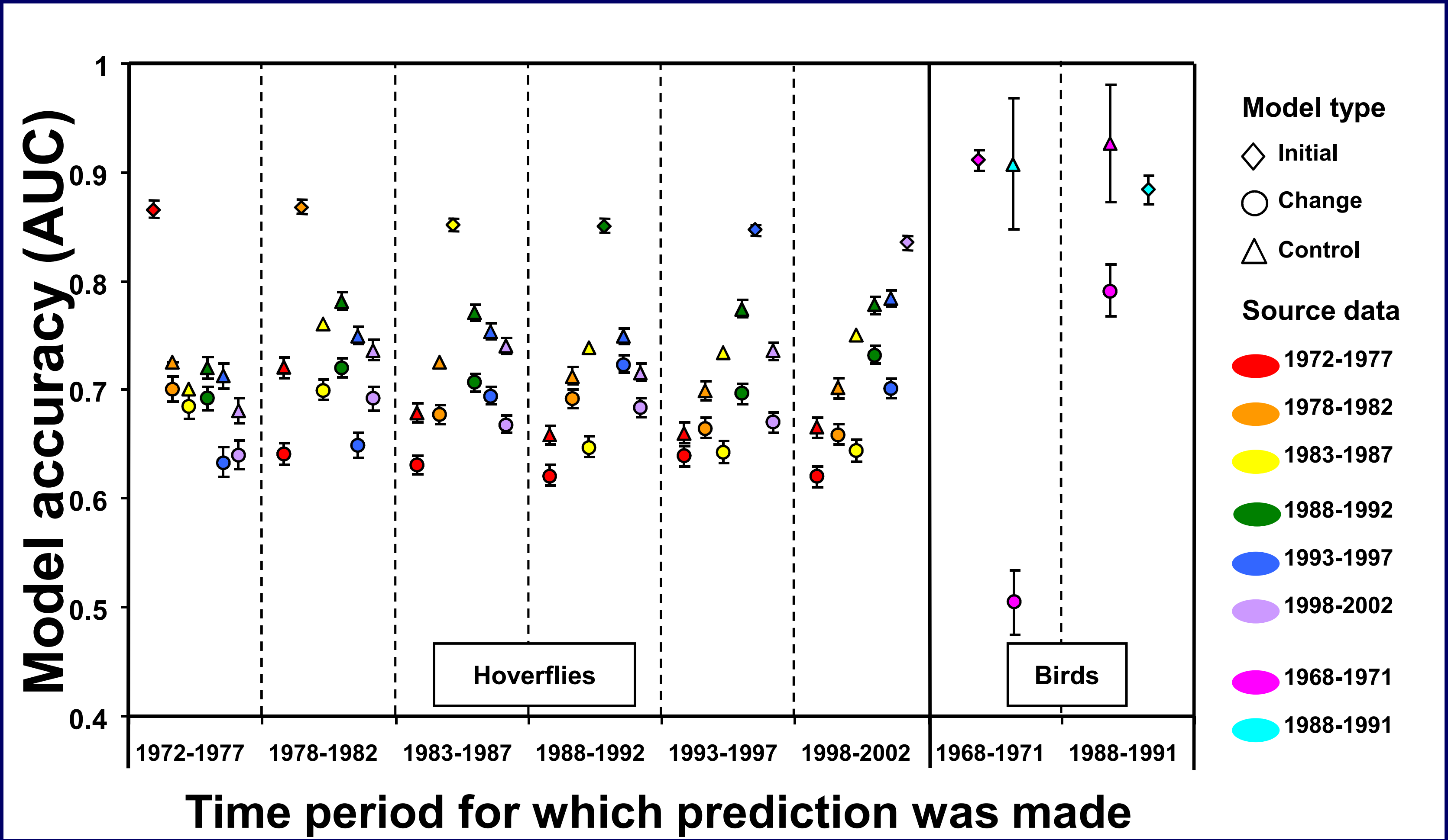


Testing the Models

- Against single-site abundance:
  - Related abundance to model probabilities using a GLM with negative binomial errors (slope & AIC)

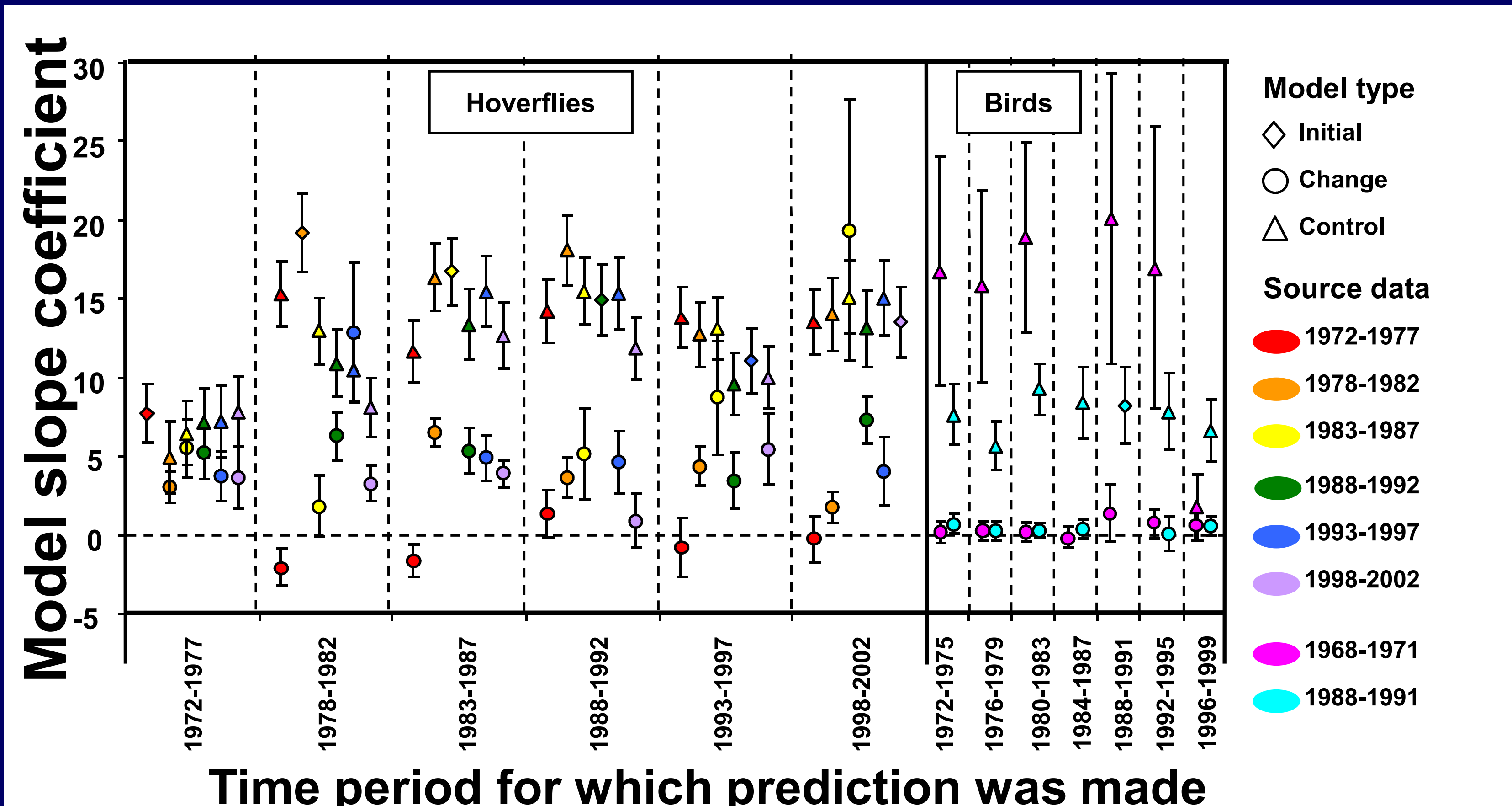


Testing Against Nationwide Occurrence Data



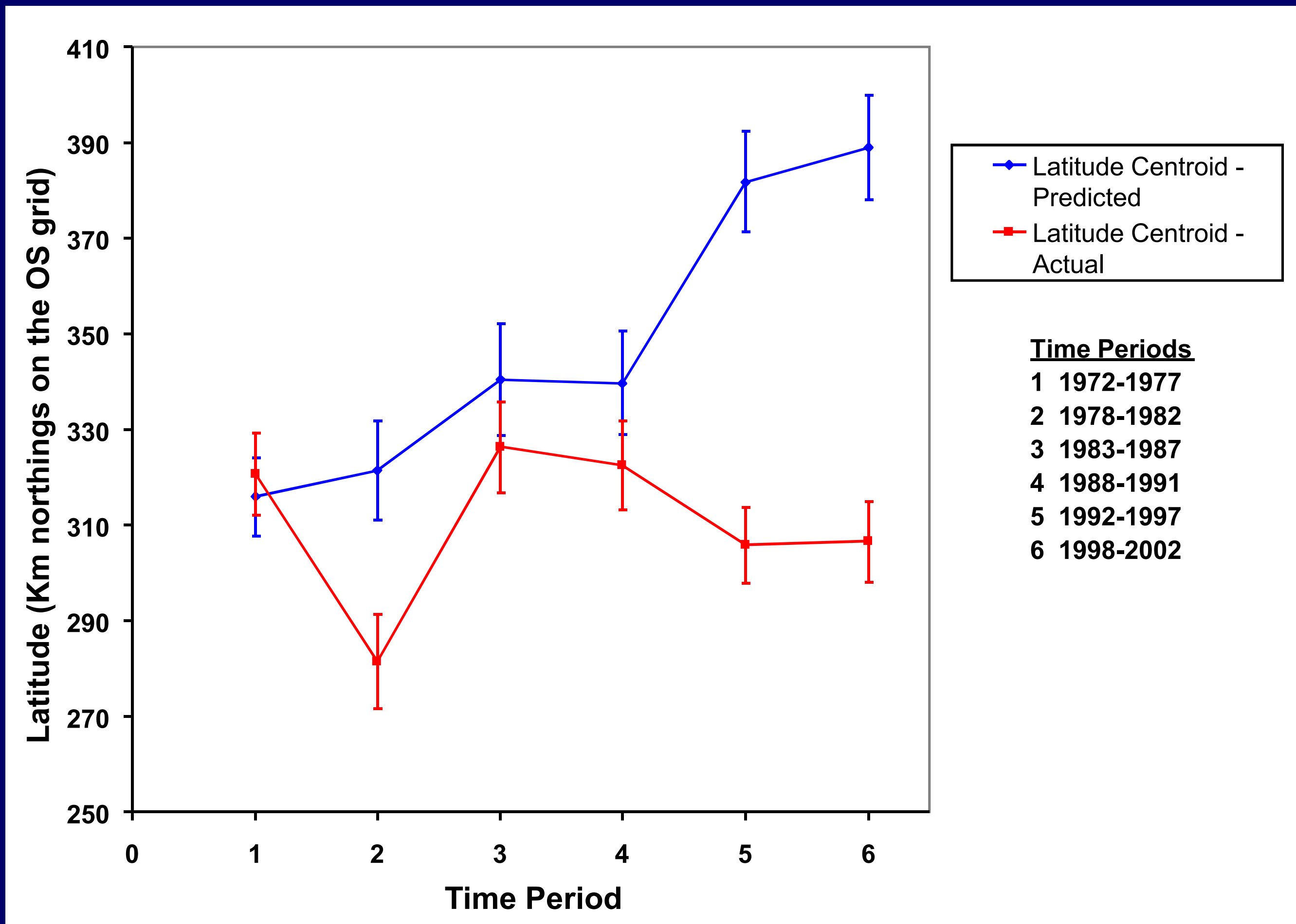
Wilcoxon matched-pairs statistic always >2.3 ($p < 0.05$) and usually >3.4 ($p < 0.001$)

Testing Against Single-Site Abundance Data



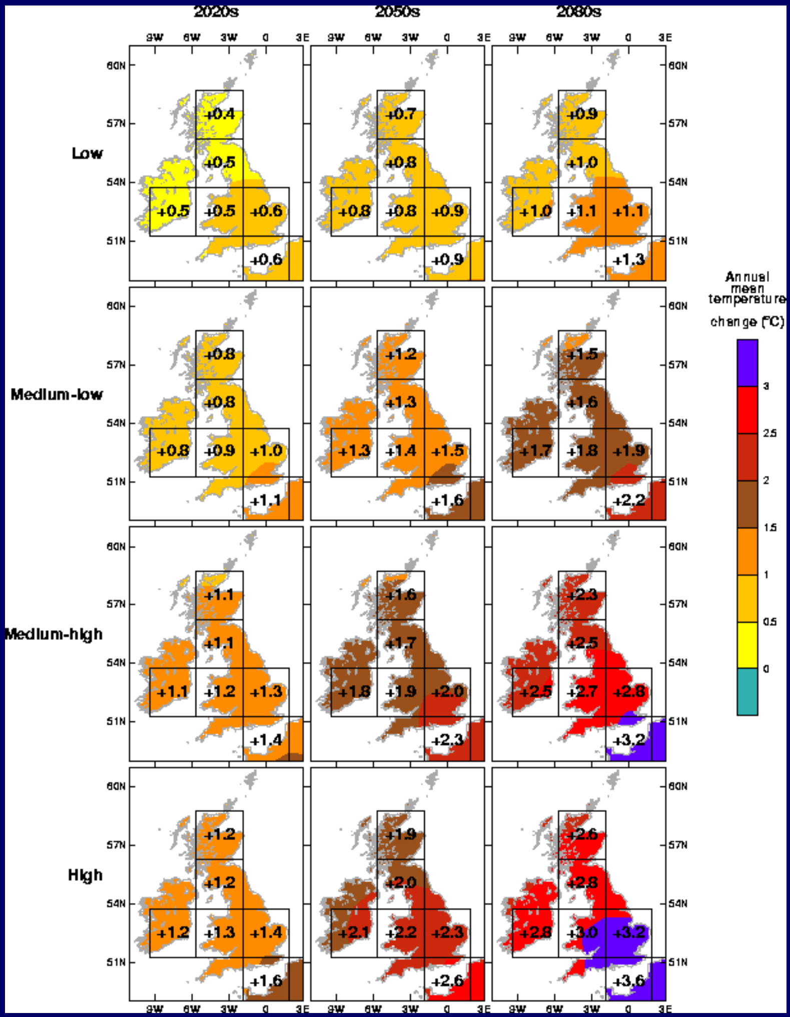
In all but 2 cases, slope coeff. greater than for control models and in all but 2 cases AIC less for control models

A Northward Shift?



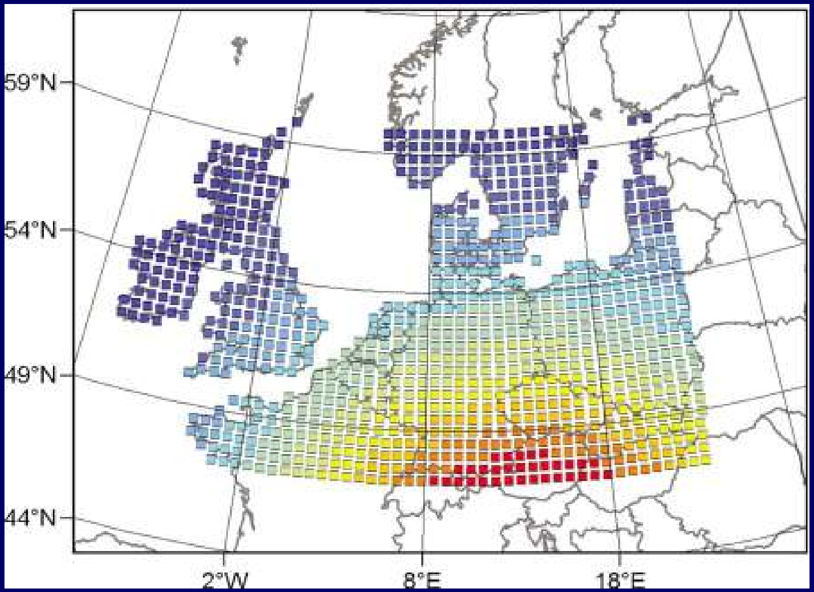
Uncertainties

- Predictions of future climate
- Getting better all the time
- Not an issue in our study



Dispersal Limitation

- Can species move fast enough?
- Svenning et al. (2008)
- Plants still not at equilibrium after post-glacial expansion



Interactions Among Species

- Known to be important for current distributions
- E.g. butterflies and host plants Araujo & Luoto (2007)
- Not considered in climate change models

Adaptation

- Evolutionary adaptation (~30 generations?)
- Phenotypic plasticity
- E.g. great tits in Wytham woods
  Charmantier et al. (2008)

Changes in Population Trends

- Some evidence for rare birds in Britain
  Green et al. (2008)
- But poor relation to abundance here
- Sites at range boundaries

Conclusions

- Models captured current distributions very well
- But failed to predict ‘future’ distributions accounting for climate change
- Very important given the popularity of these methods

Acknowledgements

- My collaborators
  - Tom Reader
  - Francis Gilbert
  - Stuart Ball
  - Simon Gillings
  - Jenny Owen
  - Chris du Feu
  - Ahmed El Gabass
  - Samy Zalat
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- NERC

The University of Nottingham

Joint Nature Conservation Committee

BTO British Trust for Ornithology

Natural Environment Research Council